Chemical Process Instrumentation
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Lecture – 24
Pressure Measurement: Moderate and High Pressure Measuring Instruments (Contd.)

Welcome to lecture 24. In our previous lecture, we have talked about bourdon pressure gage, which was an elastic element type pressure gauge. In this lecture we will talk about other 2 elastic element type pressure gauge. Such as, bellows and diaphragm gauge.

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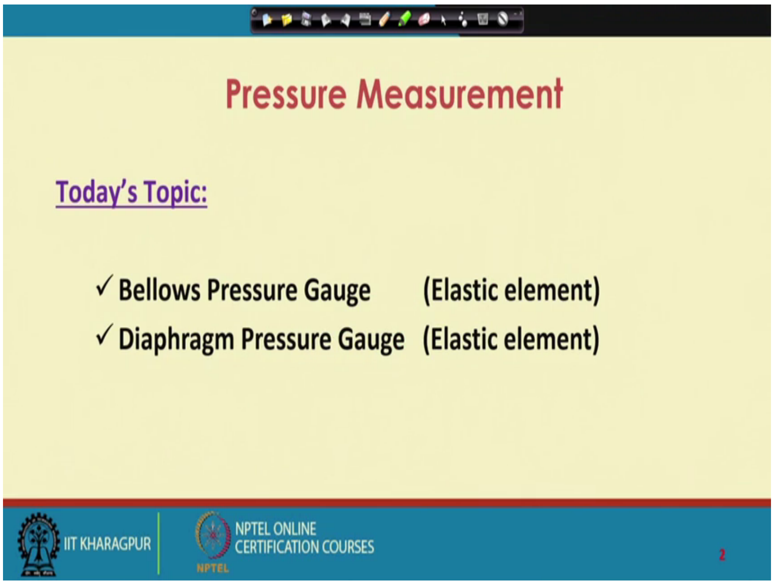

So, todays topic is bellows pressure gauge and diaphragm pressure gauge. Both are elastic element type.

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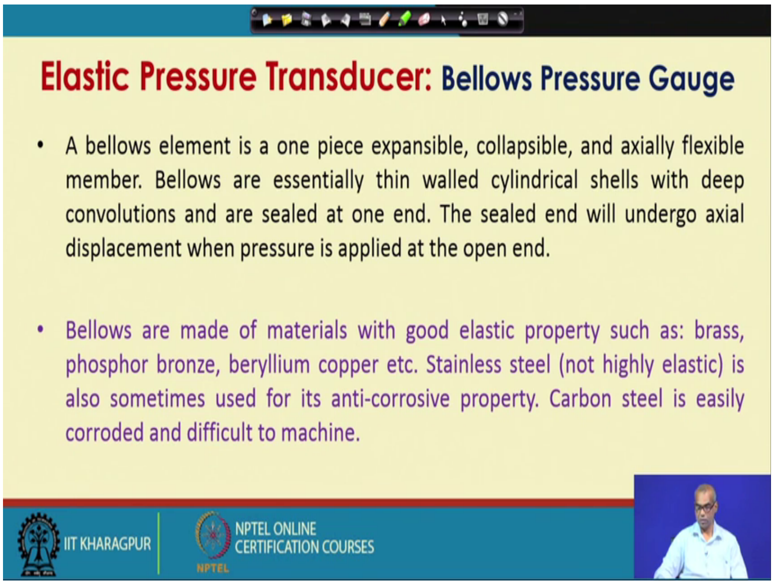

So, let us start our discussion with bellows pressure gauge. A bellows element is a one piece expansible collapsible and axially flexible member. Bellows are essentially thin walled cylindrical shells with deep convolutions and are sealed at one end. The sealed end and will undergo axial displacement when pressure is applied at the open end. Bellows are made of materials with good elastic property such as brass, phosphor, bronze, beryllium, copper etcetera. Stainless steel although not highly elastic is also sometimes used for it is anti-corrosive property. Carbon steel is easily corroded and difficult to machine, so avoided.

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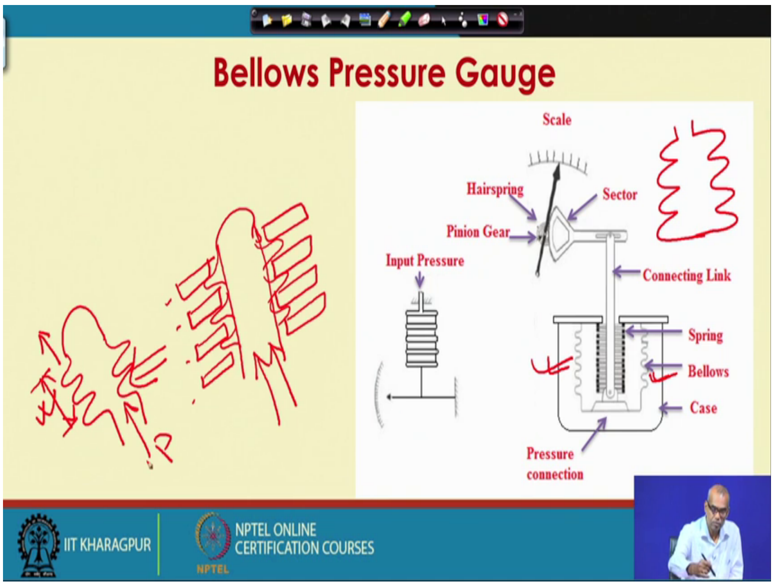

So, this is a schematic of bellows element. So, basically you have convulsions like this. Bellows are made as follows. You take a thin walled tube which is sealed at one end. This (Refer Time: 02:29) is made of materials as phosphor, bronze, beryllium, copper as you mentioned in the previous slide.

Now, there is a special die, and you have put the bellows element within this die. Now we apply very high fluid pressure here very, very high fluid pressure. If you do that, like these are very rigid. So, the bellows element now it is not bellows element now as of now it is a thin walled tube this thin walled tube will collapse and flow through this slots like this. So, in one shot you will convert the thin walled tube to an element like this, which is known as bellows. Now when I apply pressure here, there will be displacement. This displacement is a measure of this pressure.

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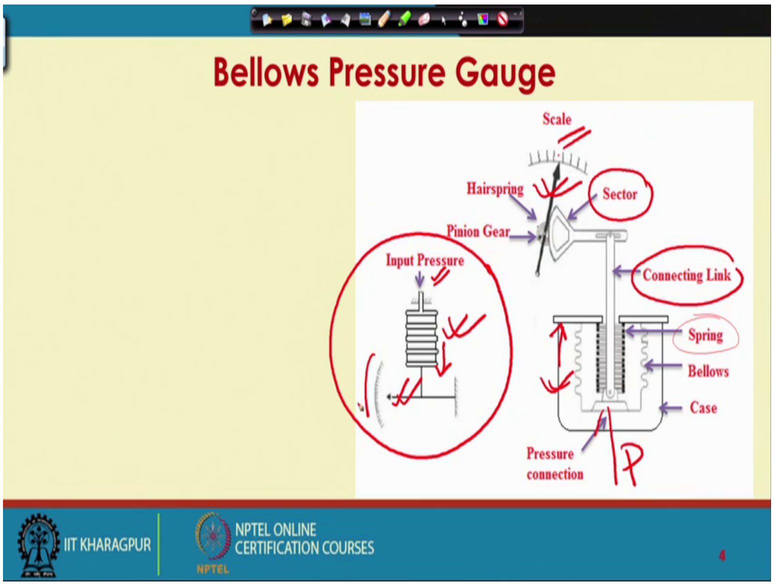

So, this is that bellows element, to add to it is elastic property, we have put spring inside.

So, as we apply pressure, the bellows element expands. So, there is displacement. You use a connection link, and pinion sector assembly to convert this displacement to a rotation of the pointer against this scale. So, from the location of the pointer against this scale you can directly read the pressure after suitable calibration. The same thing is schematically represented by a simple diagram here. This is the bellows element, these are the convolutions. So, when you apply pressure this will expand. So, this pointer will deflect against this scale.

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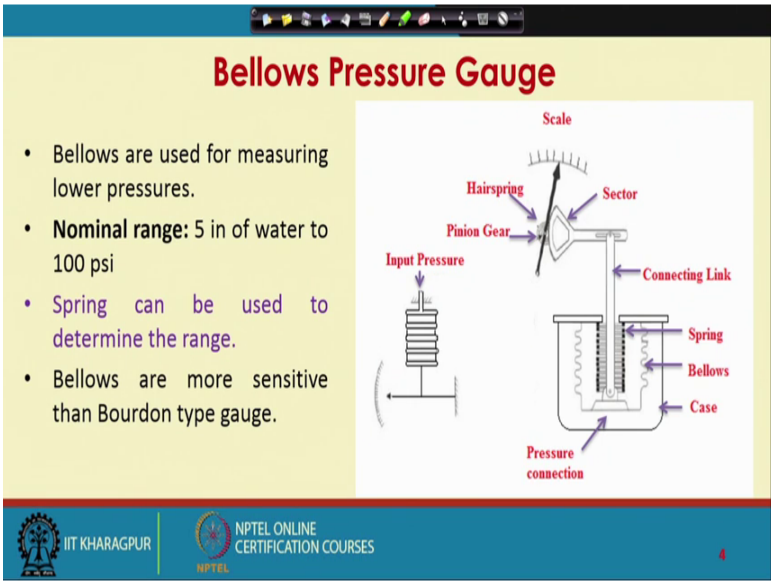

So, bellows are used for measuring low pressures, nominal range is 5 inch of water to 100 psi. This is an indicative range. Spring can be used inside the bellows to add to elasticity and also to determine the range. Bellows are more sensitive than bourdon gauges.

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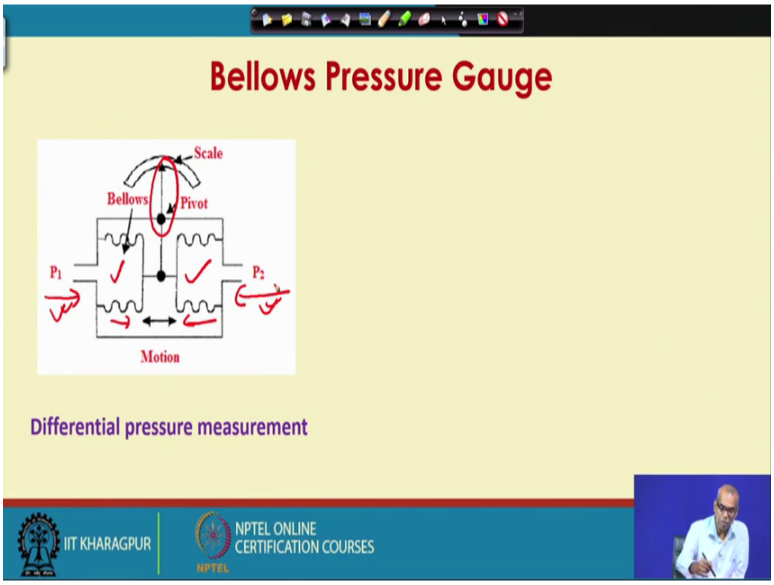

You can use bellows elements to measure differential pressure. Note that to measure differential pressure, I make use of 2 bellows elements. So, I connect this bellows element with one pressure source. I connect this element with another pressure source.

Both source displacement, and this pointer shows the resulting displacement. So, displacement of this pointer is a measure of difference between these 2 pressures. So, that way it shows differential pressure.

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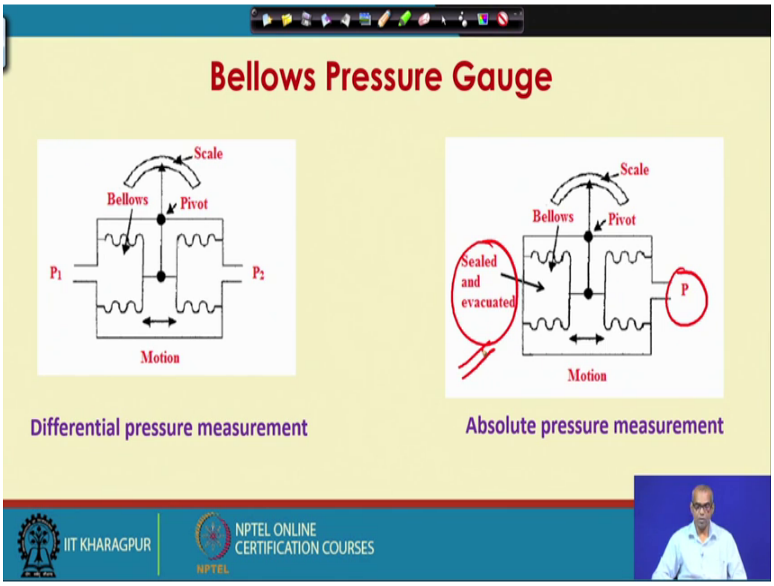

Now, if I seal one bellows element and completely evacuate it, then I measuring this pressure against vacuum. So, by definition it is absolute pressure measurement.

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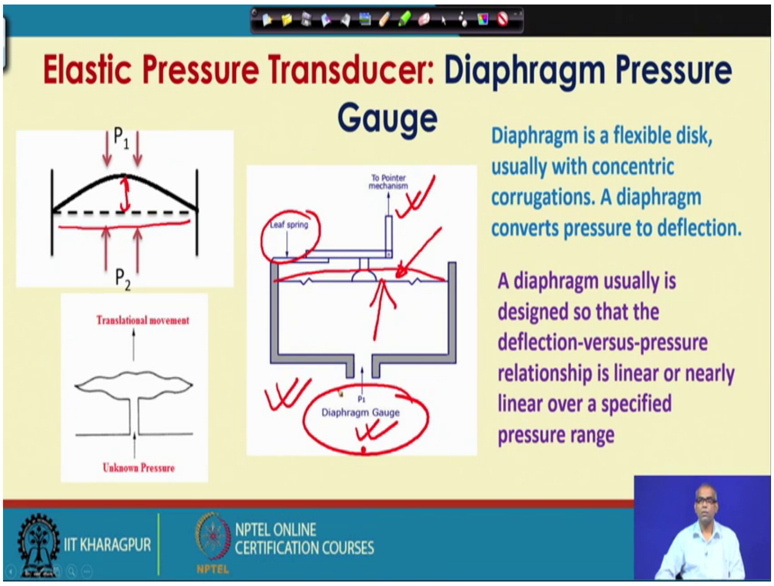

So, bellows element can be used to measure differential pressure as well as absolute pressure. Next let us talk about another elastic element type pressure gauge diaphragm pressure gauge. Diaphragm is a flexible disk usually with concentric corrugations. A diaphragm converts pressure to deflection. This is similar to bourdon tube as well as bellows elements. So, bourdon tubes, bellows, elements diaphragm all convert pressures to displacement of deflection.

So, this shows a diaphragm if we apply pressure, it will show deflection. This deflection is a measure of the pressure being applied. So, look at this figure. This is the diaphragm you apply pressure here. So, there will be displacement of this diaphragm. May be such deflection it can show. So, we have a spring attached, and this diaphragm is connected to a pointer mechanism from which you can read the displacement of the diaphragm directly. So, that displacement is related to the pressure being applied inside the diaphragm.

So, essentially diaphragm is a flexible disk and it usually has concentric corrugations. Diaphragm is usually designed so that the deflection versus pressure relationship is linear or nearly linear over a specified pressure range. This is desirable for many other instruments as well.

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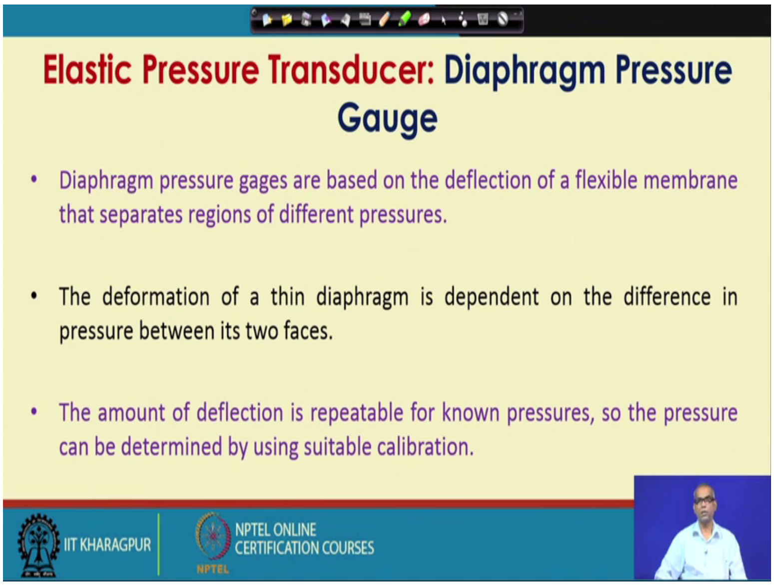

Diaphragm pressure gauge is a based on the deflection of a flexible membrane. That separates regions of different pressures. The deformation of a thin diaphragm is dependent on the difference in pressure between it is 2 faces. The amount of deflection is repeatable for non-pressures. So, the pressure can be determined by using suitable calibration.

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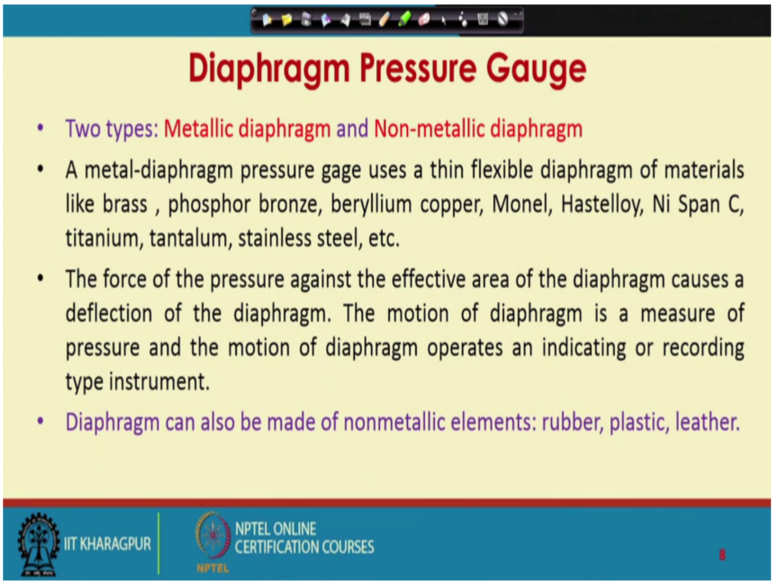

Diaphragm can be of 2 types, metallic diaphragm and non-metallic diaphragm. So, metallic diaphragms are made of thin metals and non-metallic diaphragms are made of other elastic membranes. Such as teflon, leather etcetera. Metallic diaphragm since they are made of metals, we can choose metals with good elastic property, such as phosphor, bronze, beryllium, copper, monel, etcetera. Non-metallic diaphragm does not have so good elastic properties. So, non-metallic diaphragms are generally spring loaded to add elasticity to it. A metal diaphragm pressure gauge uses a thin flexible diaphragm of materials like brass, phosphor, bronze, beryllium, copper, monel, hastelloy, nickel span c, titanium, tantalum, stainless steel etcetera.

The force of the pressure against the effective area of the diaphragm causes the deflection of the diaphragm. The motion of the diaphragm is a measure of pressure, and the motion of diaphragm operates an indicating or recording type instruments. So, you can not only attach a pointer and scale with the diaphragm to read it is deflection. You can also attach a pin so that you can record the readings. So, the deflection can be actuated the movement of a pointer against the scale, similarly the deflection can be used to actuate the movement of a pin say against a paper. In that case we will have a written record of the pressures.

Diaphragm can also be made of non-metallic elements such as rubber plastic leather.

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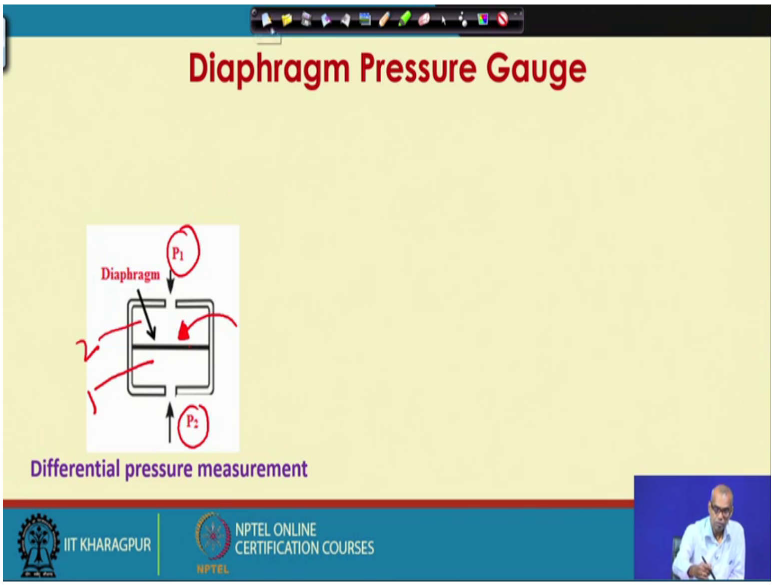

And when diaphragms are made of non-metals as I told you they are usually spring loaded so that the elastic properties improved. Diaphragm pressure gauge can be used to measure differential pressure. As the diagram shows to measure differential pressure you must have 2 chambers. So, this is one chamber, and this is another chamber, and you have this diaphragm. So, apply pressure P 1 here, apply pressure P 2 here, the deflection of this diaphragm will depend on both P 1 and P 2. So, the net deflection of the diaphragm will depend on the difference between these 2 pressures, and that way we can measure differential pressure. Of course, we have to attach a pointer and scale type of mechanism with this diaphragm.

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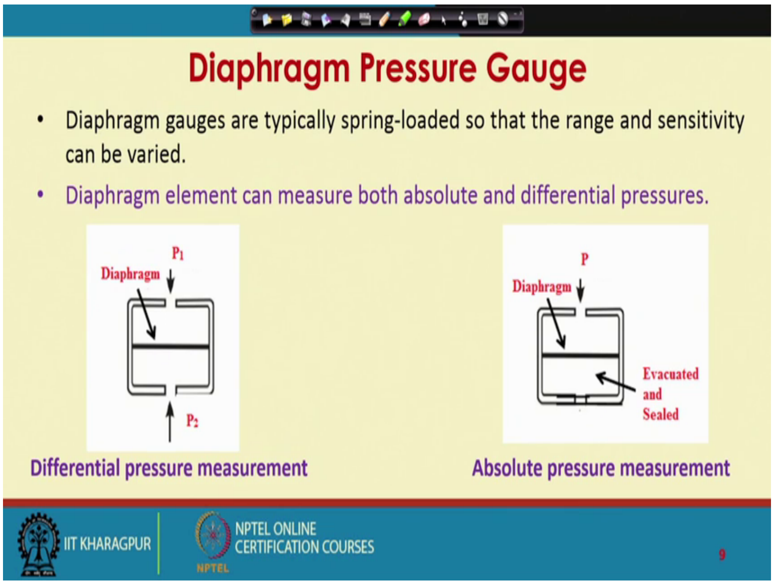

Again, if one end if one chamber is sealed and completely evacuated; that means, it is under vacuum, then the pressure is being measured against vacuum. So, you can measure absolute pressure. Similar arrangement we have also seen in case of bellows. This chamber you apply pressure and this chamber is completely evacuated. So, the deflection of this bourdon tube; sorry, deflection of this diaphragm is being measured against this vacuum. So, you measure absolute pressure here.

Diaphragm gauges are typical spring loaded so that the range and sensitivity can be varied. So, you can add elasticity to diaphragms, particularly non-metallic diaphragms, by making it is spring loaded, but not only that by introducing spring, we can also change the range and sensitivity of the diaphragm pressure gauges.

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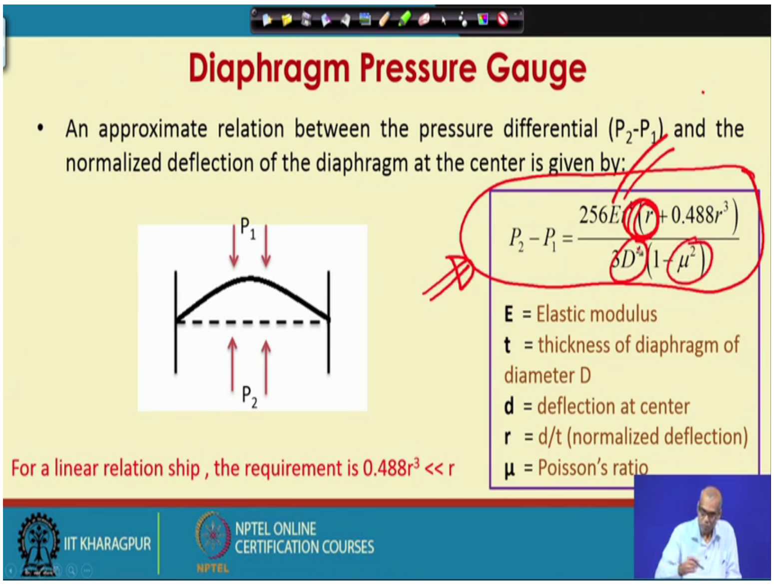

Here we present an empirical relations between the pressure differential and the deflection of the diaphragm at the centre. We express the deflection as normalised deflection of the diaphragm at the centre. The normalised deflection at the centre is the deflection at centre divided by thickness of the diaphragm. So, this equation gives us a relationship between the differential pressure P 2 minus P 1 with r which is normalised deflection.

So, the equation is an empirical equation it tells us the differential pressure is directly proportional to the modulus of elasticity of the material chosen. It is proportional to the thickness of the diaphragm varies as thickness to the power. 4 it depends on the it depends on the normalised deflection r which is deflection at centre divided by the thickness of the diaphragm, the diameter of the diaphragm is D and mu is poisons ratio. So, these are the parameters on which the deflection of the diaphragm will depend. If you can neglect this power, then P 2 minus P 1 and r which is normalised deflection because for a given diaphragm. The modulus of elasticity the thickness of the diaphragm and the diameter of the diaphragm and the position ratio all are constant.

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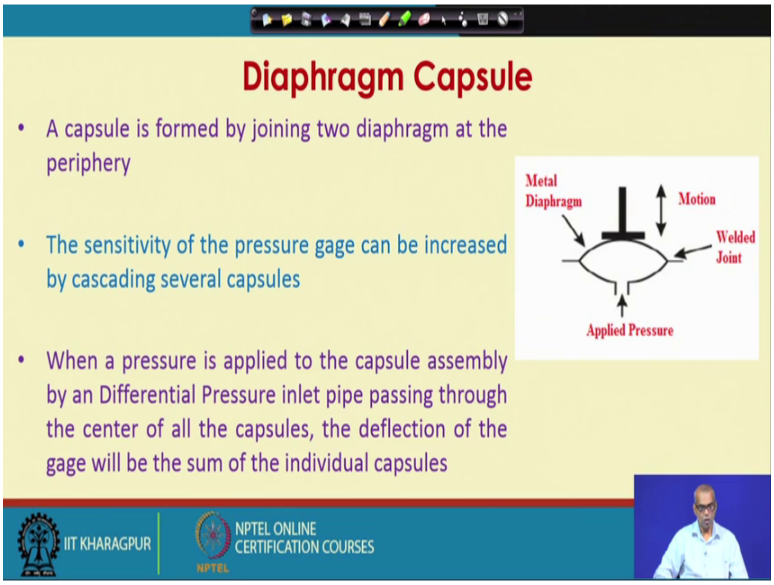

Now, let us talk about diaphragm capsule. A capsule is formed by joining 2 diaphragm at the periphery. So, 2 diaphragms we have joined at the periphery and as formed a capsule. So, if I apply pressure inside this capsule. So, it will show displacement. The sensitivity of the pressure gauge can be increased by cascading several capsules. So, you take several such capsules and form a cascade, then I apply pressure inside all such capsules will deflect individually so the overall displacement or deflection will be much more. So, that way the sensitivity of the pressure gauge can be increased by cascading several capsules in series.

When a pressure is applied to the capsule assembly by a differential pressure inlet pipe passing through the centre of all the capsules the deflection of the gauge will be the sum of the individual capsules.

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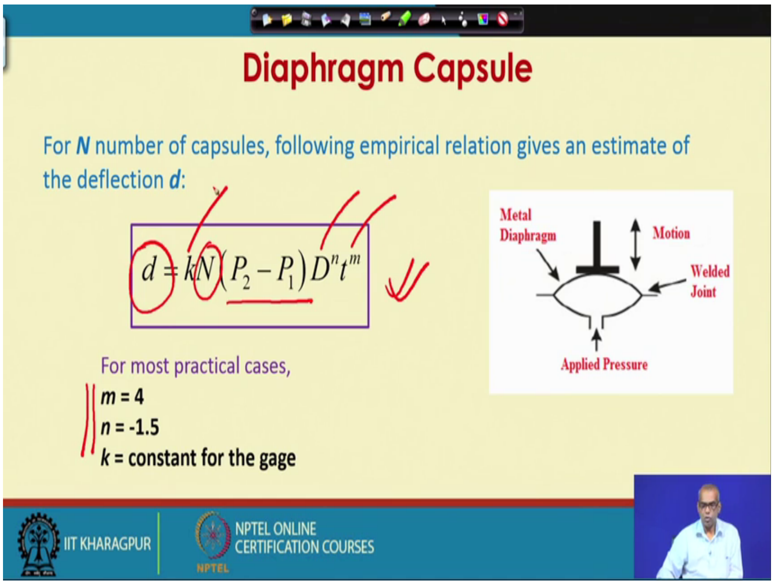

If you have n number of capsules, then this empirical relation gives an estimate of the total deflection D. It tells you the total deflection D of an capsule assembly will depend on the number of capsules which is obvious the differential pressure which is also obvious, diameter thickness. For most practical cases, the value of m equal to 4 and n equal to minus 1.5 is used to represent the relationship. The k is a constant for the gauge.

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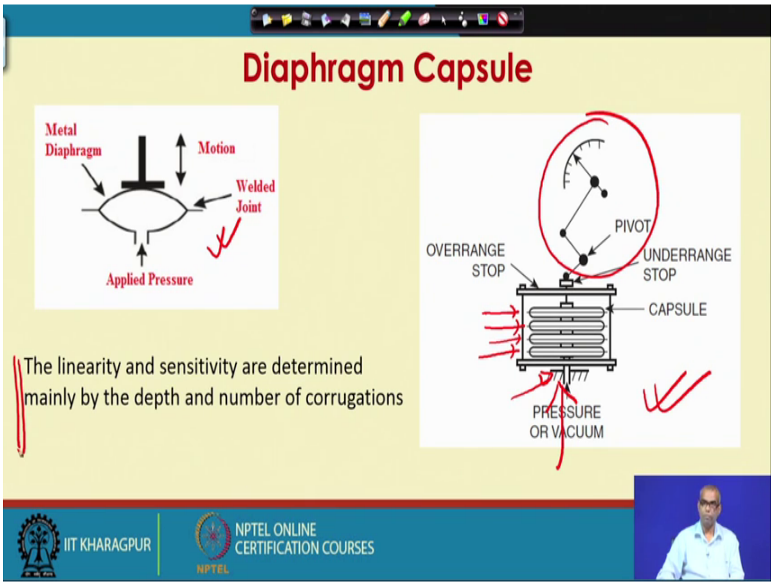

So, this is the better picture of those capsule assembly. These are individual capsules. So, this individual capsules are put 1 over another and a cascade is formed. Look at this pipe which passes through the centre of this capsules. So, when you apply pressure inside this tube, each capsule receives this power and they deflect individually. So, the overall deflection is sum of the individual deflections. So, if you compare with one capsule assembly of capsules will get much more deflection. So, sensitive will increase. This deflection is used to move this pointer against this scale, and from the scale you can directly read the value of the pressure.

The linearity and sensitivity can be determined mainly by the depth and number of corrugations of diaphragm.

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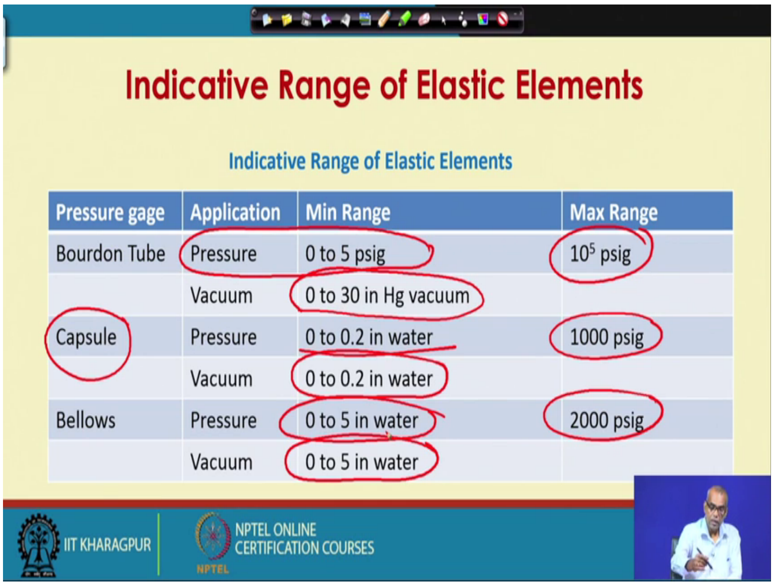

Pressure gage	Application	Min Range	Max Range
Bourdon Tube	Pressure	0 to 5 psig	10^5 psig
	Vacuum	0 to 30 in Hg vacuum	
Capsule	Pressure	0 to 0.2 in water	1000 psig
	Vacuum	0 to 0.2 in water	
Bellows	Pressure	0 to 5 in water	2000 psig
	Vacuum	0 to 5 in water	

This is an indicative range of elastic elements as of now we have talked about 3 types of elastic pressure elements. The bourdon tubes, diaphragm gauge and bellows. All gives deflection as output and receives pressure as input. So, here we represent an indicative range over which this pressure elements can be used. Bourdon tube when used to measure pressure. The minimum range is about 0 to 5 psig. And maximum range is 10 to the power 5 psig. Bourdon tube when used to measure vacuum, we can measure up to 30 inch of mercury vacuum. This is diaphragm capsule. In the minimum range for pressure measurement is 0.2 inch of water, and the maximum range is thousand psig. When the diaphragm capsule is used to measure vacuum is 0 to 0.2-inch water. Bellows, the minimum range of pressure measurement is 0 to 5 inch of water, and the maximum range of pressure measurement is 2,000 psig. Bellows when we used to measure vacuum it measure 0 to 5 inch of water. So, these are an indicative range; not a very rigid range, but some idea about the rangers over which such elastic pressure elements can be used. So, I stop the lecture here.